DRA / LANGLEY

(NASA-CR-173708) NOISE PATH IDENTIFICATION USING FACE-TO-FACE AND SIDE-BY-SIDE MICROPHONE ARRANGEMENTS (Purdue Univ.) 28 p HC A03/MF A01 CSCL 20A

N84-28569

Unclas
G3/71 00660

RAY W. HERRICK LABORATORIES

A Graduate Research Facility
of The School of Mechanical Engineering

purdue university

Purdue University

West Lafayette, Indiana 47907

transform (FFT) based analyzers in recent years, the technique was not practical. The most commonly used method of measuring the acoustic intensity is based on finite difference approximation and the intensity is calculated from the imaginary part of the cross spectrum between two closely spaced microphones. The successful application of the cross-spectral formula based on finite difference approximations is subject to low and high frequency limits dictated by the effective microphone separation distance. Other errors associated with the technique include phase mismatch between the two microphone systems, scattering of the sound by the microphones and the shadowing effect of one microphone on the other.

A major part of this report will be presented at the 1984 International Conference on Noise Control Engineering to be held in Hawaii in December.

3. MICROPHONE ARRANGEMENTS

Although four possible microphone configurations shown in Fig. 1 have been suggested for measuring the acoustic intensity, only two, the side-by-side and face-to-face are primarily used. Shadowing of one microphone by the other and small microphone spacings are major drawbacks in the case of back-to-back and staggered configurations. The major advantages of using the side-by-side arrangement are that one can sweep close to the radiating surface and conventional spherical windscreens can be

NOISE PATH IDENTIFICATION USING FACE-TO-FACE AND SIDE-BY-SIDE MICROPHONE ARRANGEMENTS

1. ABSTRACT

In large complex structures, with several major sound transmission paths and high levels of background noise, it can be a complex task to locate and rank the contribution of an individual sound transmission path. In this paper the two-microphone acoustic intensity techniques as a tool for path identification was experimentally investigated. Laboratory tests conducted on the fuselage of a light aircraft indicate that, if the intensity transmitted through a particular section of the fuselage is measured in the presence and absence of flanking paths using the face-to-face and side-by-side microphone arrangements, then no significant difference exists between the two measured intensities if the face-to-face microphone arrangement is used. However, if the side-by-side arrangement is used, then considerable difference exists between the two measured intensities. Comparison of the two microphone arrangements in the absence of flanking, but presence of increasing background noise suggests that, if the sound field is very reactive then error is introduced into the measured intensity. However, the magnitude of the error is similar in both arrangements.

2. INTRODUCTION

A common step in solving any noise control problem is to identify and characterize which one of the several source/path is the one that dominates. Knowing the noise contribution of each source/path can often lead to a quick, logical and direct approach in developing noise control techniques. Sound pressure level measurements in the presence of various source/path does not provide any information concerning the amount and direction of the acoustic energy flow and as such cannot be used to rank the contribution of any individual source/path. Hence, the basic principle employed in traditional source/path identification techniques is to artificially quieten or eliminate other sources/paths, except the one under investigation and each source/path is returned to its natural state, with others "silenced" to complete the source/path analyses. The eliminating and quietening of other sources/paths can be achieved by disconnecting the noisy sources or by lead wrapping. These methods can be very expensive and time consuming when dealing with structures of the size of a light aircraft. Also, due to the poor transmission loss of lead at low frequencies, such wrapping techniques are often not very successful.

A possible solution to this ranking problem is to measure the acoustic intensity vector, which describes the net flow of acoustic energy. The concept of measuring the acoustic intensity is not new, the theoretical background has been available since 1932. However, until the advent of real time fast fourier transform (FFT) based analyzers in recent years, the technique was not practical. The most commonly used method of measuring the acoustic intensity is based on finite difference approximation and the intensity is calculated from the imaginary part of the cross spectrum between two closely spaced microphones. The successful application of the cross-spectral formula based on finite difference approximations is subject to low and high frequency limits dictated by the effective microphone separation distance. Other errors associated with the technique include phase mismatch between the two microphone systems, scattering of the sound by the microphones and the shadowing effect of one microphone on the other.

A major part of this report will be presented at the 1984 International Conference on Noise Control Engineering to be held in Hawaii in December.

3. MICROPHONE ARRANGEMENTS

Although four possible microphone configurations shown in Fig. 1 have been suggested for measuring the acoustic intensity, only two, the side-by-side and face-to-face are primarily used. Shadowing of one microphone by the other and small microphone spacings are major drawbacks in the case of back-to-back and staggered configurations. The major advantages of using the side-by-side arrangement are that one can sweep close to the radiating surface and conventional spherical windscreens can be used when the fluid has mean flow, however, the microphone spacing is limited by the size of the microphones. Small separation distance necessarily for high frequency measurements are easily obtainable in the face-to-face configuration. The main disadvantage of this configuration is that the incidence angles as shown in Fig. 2 are different for the two microphones; 0° for the second microphone and 180° for the first. As a consequence the scattering effects of the two microphones are different. To overcome this problem, a solid cylindrical spacer is inserted between the two microphone grids as shown in Fig. 2. The cylindrical spacer produces a small volume between the spacer and the diaphragm of each microphone. This volume is acoustically coupled to the sound field via the slits in the microphone grid. Thus the incident sound field activates the diaphragm only via the peripheral slits.

4. ACOUSTIC INTENSITY MEASUREMENTS

In practical situations acoustic intensity measurements are generally made by sweeping the microphone array over the radiating surface to get a space and time averaged intensity. In the past three years several researchers have begun to apply the acoustic intensity technique to noise transmission problems in aircrafts with considerable success (1,2). However, since the acoustic intensity is calculated from the pressure measured by the two microphones, in many practical situations where high amounts of background noise is present, the use of the technique is limited. Crocker, Heitman and Wang (3) presented the results of a laboratory study on the transmission of sound through four areas of an airplane fuselage sidewall using the side-by-side two microphone intensity configuration. Part of their study suggested that if there are strong flanking paths present, inaccurate estimates can be obtained of the sound transmitted by the primary sound transmission path, thus further limiting the "in situ" use of this technique. However, their study indicates that if fairly simple precautions are taken to suppress background noise and strong flanking paths than the technique can be highly successful in predicting the sound transmission characteristics of aircraft.

The purpose of this paper is to present and discuss some experimental results on the validity of the two microphone acoustical intensity data in noise path identification. The data was taken in the presence of various flanking paths and increasing amounts ot background noise using the side-by-side and face-to-face microphone configuration. It's important to assess the application of the two-microphone acoustic intensity technique under such "real life" situations if this technique is to be used for "in situ" measurements.

5. EFFECT OF FLANKING PATHS

The fuselage of a small single engine Piper Cherokee aircraft was the subject of the first set of results presented in this study. The fuselage was suspended in a semi-anechoic chamber from three points. The chamber itself is 12.5 x 8.2 x 5.5 m and has concrete floors. Fiberglass sheets were placed beneath the fuselage, to make the environment essentially anechoic. Four areas of the starboard fuselage sidewall were chosen for the flanking path studies. The four areas are shown in Fig. 3 and include two plexiglass windows and two aluminum panels with standard trim. One of two plexiglass window was part of the door unit, while the other was a passenger window behind the door. Similarly one of the aluminum panels was located beneath the back passenger window. For ease of reference the areas under study have been numbered as shown in Fig. 3. A 25.4 thick sheet of plywood with a 50.8 mm thick sheet of fiberglass attached separated the cabin from the back of the fuselage and all tests were performed with this construction in place. A pneumatic driver with a rectangular horn attached was used as the sound source and was located directly opposite the center of the rear window (panel 1) as indicated in Fig. 4.

The acoustic intensity transmitted was measured in the presence and absence of flanking paths using the two different microphone arrangements, namely side-by-side and face-to-face. For example, with the sound source located directly in front of the rear window the intensity transmitted through panel 4 was measured. In this situation, panels 1, 2, and 3 will act as flanking paths, with panels 1 and 3 being strong flanking paths because of their low transmission loss and the source location. The flanking paths were than avoided by covering panels 1, 2 and 3 with two sheets of lead vinyl (3.7 kg/m^2) such that the transmission loss of these panels was relatively much higher than the panel under study and the intensity transmitted through panel 4 was remeasured. If the effect of flanking on the microphone configuration is negligible than the effect of covering panels 1, 2, and 3 should not change the measured value of the intensity transmitted through panel 4, provided the interior surface of this panel can be assumed non absorbing. Similar tests were also conducted on panel 3 with panels 1, 2 and 4 acting as flanking paths. In this situation, panel 1 will be a major flanking path because of the source location and panels 2 and 4 were not considered as flanking paths because of their high transmission loss and location relative to the source. However, all three panels were covered with two sheets of lead vinyl when the blocked flanking path measurements were made.

Half inch phase matched Bruel and Kjaer (B&K) pair of free-field microphones mounted on 1/4"-diameter B&K microphone preamplifiers were used in this study. For the side-by-side configuration, the two microphones were supported by clamping the preamplifiers between two small pieces of rectangular poly-glass. Care was taken to position the clamping device far away as possible from the measurement point. For the face-to-face configuration, a special probe manufactured by B&K with a solid spacer was used. A dual channel FFT was used for the intensity calculations. The data was recorded as narrow 10 Hz bandwidth measurements. With the help of a specially written fortran program, it was possible to convert the data into one-third octaves band intensity levels. A reasonable amount of fiberglass was placed inside the aircraft to make the interior reasonably anechoic and all exterior parts of the fuselage except the four areas under study were covered with at least two sheets of lead vinyl to prevent sound entering the fuselage through other areas. Care was taken to avoid any exterior and interior fuselage and source location changes from one set of measurements to the next. Possible errors due to signal processing and FFT techniques were also avoided.

Figures 5 and 6 show the effect on the intensity transmitted by panel 4 of flanking paths 1, 2, and 3, measured using the side-by-side and face-to-face microphone arrangement respectively. Figure 5 for the side-by-side arrangement shows little effect of flanking up to about 500 Hz, above this frequency the two curves begin to diverge, the measured intensity being higher for the case of unblocked flanking paths than that found with blocked flanking paths. The divergence of the two curves is probably because at low frequencies all four panels under study will have similar transmission loss characteristics, however, at high frequencies the transmission of sound through the windows will be much higher because of their comparatively low transmission loss. Thus the higher amounts of intensity transmitted by the windows will contaminate the measured intensity transmitted by the panel under investigation. The pattern is different when the intensity transmitted under similar conditions is measured using the face-to-face arrangement, Fig. 6. In this case, a relatively small difference is observed between blocked and unblocked flanking paths. Also if the face-to-face curves are compared with the blocked flanking side-by-side curve, fairly good comparison is observed in all but one band, indicating that even when flanking is present, the face-to-face arrangement can measure the intensity transmitted fairly accurately.

A less dramatic flanking effect on the side-by-side arrangement is seen in Fig. 7, where the intensity transmitted by the door window (Panel 3) was measured in the presence and absence of flanking. Once again at high frequencies the two curves begin to diverge. As before, little difference between the two sets of data obtained using the face-to-face arrangement (Fig. 8) is observed. Also if the face-to-face curves are compared with the blocked flanking side-by-side curve, fairly good agreement is observed.

6. EFFECT OF BACKGROUND NOISE

The second set of tests to compare the two microphone arrangements were conducted using the set-up shown in Fig. 9, arranged in the semi-anechoic chamber. The arrangement consists of a fairly reverberant 1.2 M x 1.3 M x 1.8 M wooden box, with a 1.2 M x 1.2 M opening. This box on occasions has been used in the Herrick Laboratories as the acoustically hard receiving room in the transmission suite transmission loss measurement technique. A 1/8" thick steel panel with a .3 M x .45 M plexiglass window was sealed to the opening. A large Altec speaker positioned directly in front of the panel was used as a sound source. The space time averaged intensity transmitted by the plexiglass window was measured using the side-by-side and face-to-face microphone arrangements under various interior background noise conditions. The interior background noise conditions were varied by placing different amounts of fiberglass in the box. Four such conditions were studied. These included; anechoic, semi-anechoic, reverberant and noisy. In the case of the anechoic condition wedges of fiberglass similar to those commonly used in anechoic chambers were placed against the side and rear walls of the box and some fiberglass was also placed on the floor. For the semi-anechoic condition fiberglass wedges were placed only against the rear wall. The reverberant condition was achieved by removing all the fiberglass from the box and finally the noisy condition was achieved by introducing a high frequency sound source into the empty box.

Figure 10 thru 13 show the effect of increasing the background noise on the intensity transmitted measured using the side-by-side and face-to-face microphone arrangements. Intensity transmitted measured under anechoic conditions (Fig. 11) was considered as the actual intensity being transmitted through the plexiglass window and the intensity measured under other conditions were compared with the actual intensity to evaluate the effect of background noise conditions. Along with the measured intensity, the difference between the measured and actual intensity is also plotted in Figs. 11, 12, and 13. As can be seen in these figures, regardless of the background noise condition both the face-to-face and the side-by-side arrangements measure the same intensity, unlike the last section.

Figures 11 and 12 show that under semi-anechoic and even reverberant background fairly accurate estimates of the transmitted acoustic intensity can be obtained. There is an error of about 3 dB in 3 one-third octane bands at low frequencies in the case of the reverberant field. Otherwise, the conditions of the data are fairly good. Finally, in the case of noisy background condition (Fig. 13) both arrangements over estimate the transmitted acoustic intensity by more than 10 dB in certain frequency bands. Although this discrepancy was to be expected, the ultimate aim of this particular test was to see if one of the arrangements would give better results than the other in a highly noisy environment.

7. CONCLUSION

Measurement of the sound power radiated into an enclosure in the presence of flanking paths and background noise can be an expensive and time consuming task if conventional measurement techniques are used. The results of experimental investigations in this paper clearly show that the two microphone acoustic intensity approach can be utilized successfully to estimate the intensity transmitted into an enclosure even in the presence of flanking paths and fairly reverberant background conditions. Comparison of the side-by-side and face-to-face microphone arrangements suggests that when measurements are taken in the presence of flanking paths than the face-to-face arrangement should be used, however, if the side-by-side arrangement is to be used than flanking paths must be blocked.

8. REFERENCES

1. Crocker, M.J., Raju, P.K., Forseen, B., "Measurement of Transmission Loss of Panels by the Direct Determination of Transmitted Acoustic Intensity," Noise Control Engineering, 17(1), 6-12 (1981).

2. Wang, Y.S., Crocker, M.J., "Direct Measurement of Transmission loss of Aircraft Structures Using the Acoustic Intensity Approach," Noise Control Engineering, 19(3), 80-85 (1982).

3. Crocker, M.J., Heitman, K., Wang, Y.S., "Evaluation of the Acoustic Intensity Approach to Identify Transmission Paths in Aircraft Structures," SAE Technical Paper 830734 (1983).

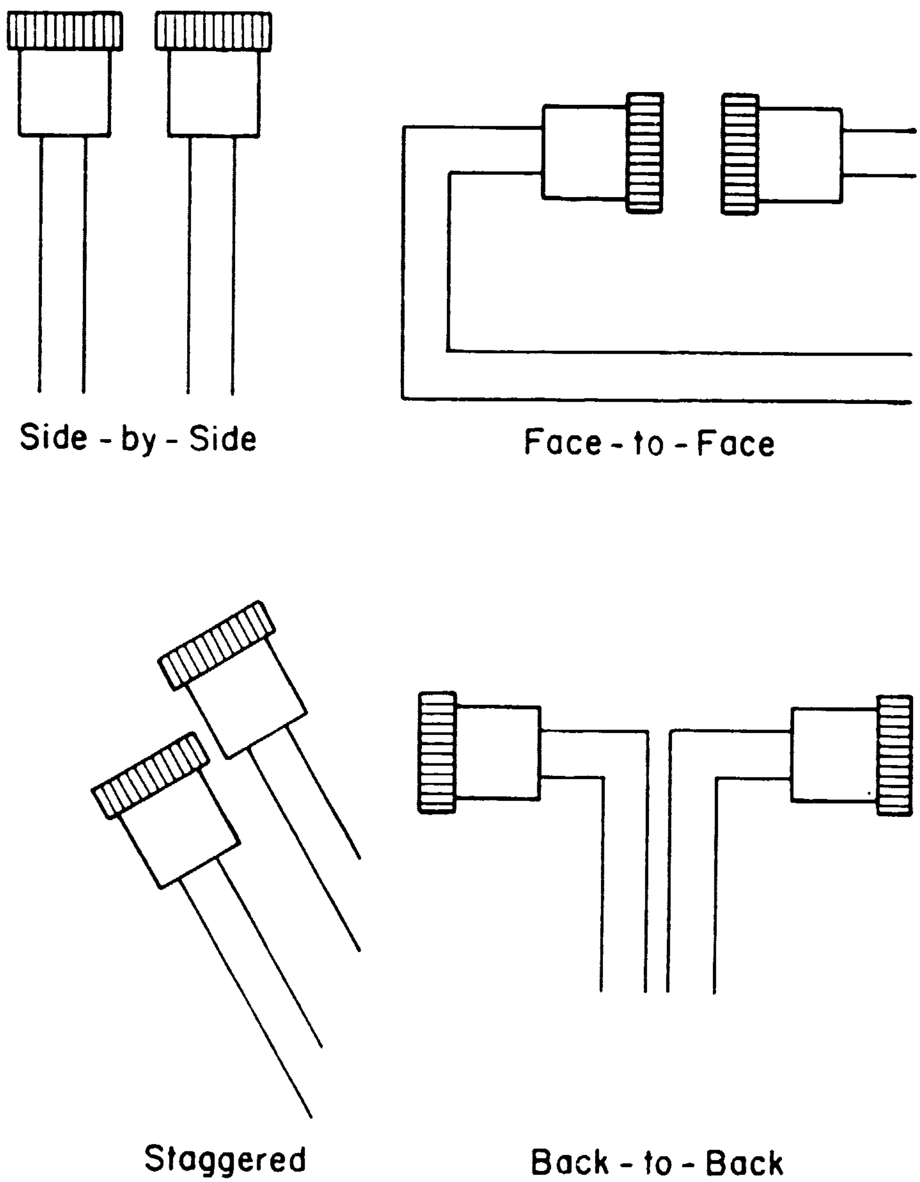


Figure 1. Microphone arrangements.

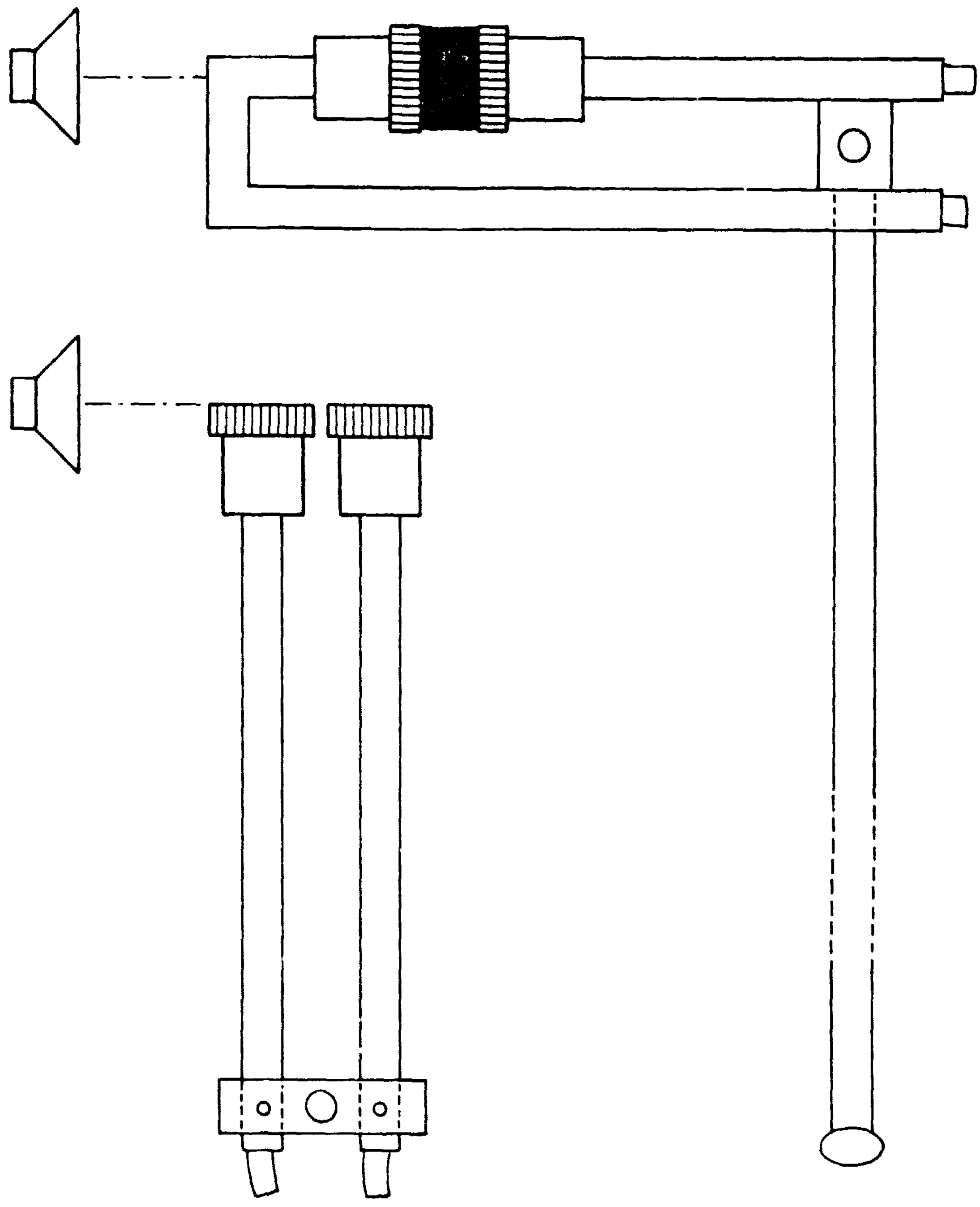
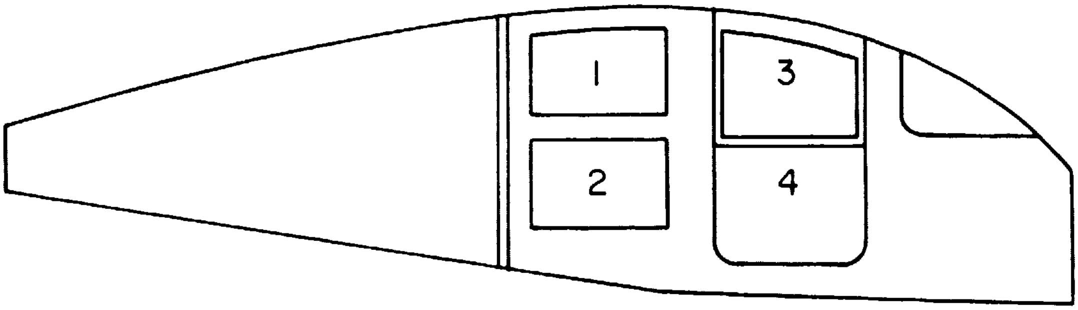


Figure 2. Set-up to measure the acoustic intensity.



1 Back Passenger Window
2 Back Passenger Panel
3 Door Window
4 Door Panel

Figure 3. Relative position of the fuselage panels under study.

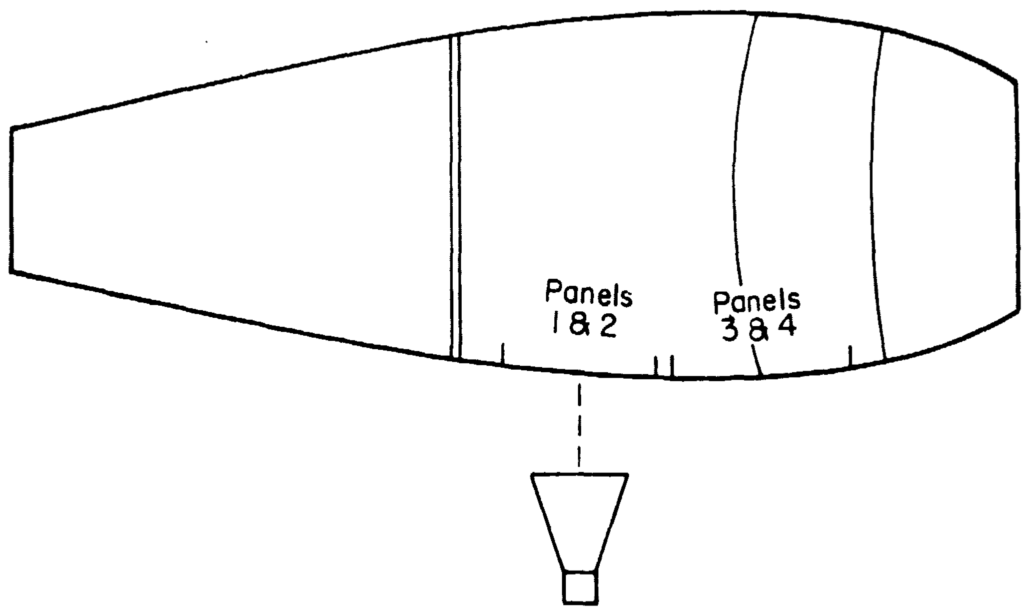


Figure 4. Position of the source relative to the panels under study.

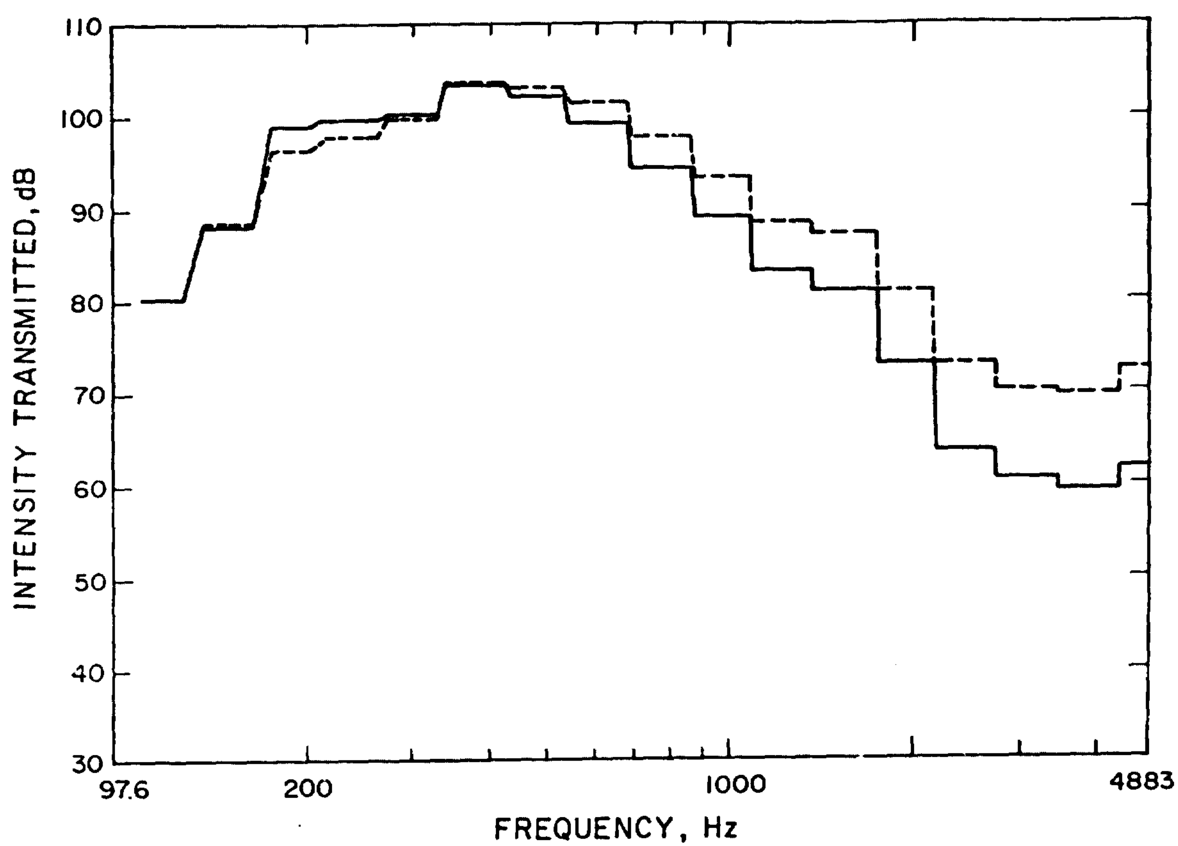


Figure 5. The effect of flanking noise on the door panel (Panel 4) transmitted intensity measured using the side-by-side microphone arrangement. —— blocked flanking paths, ---- unblocked flanking paths.

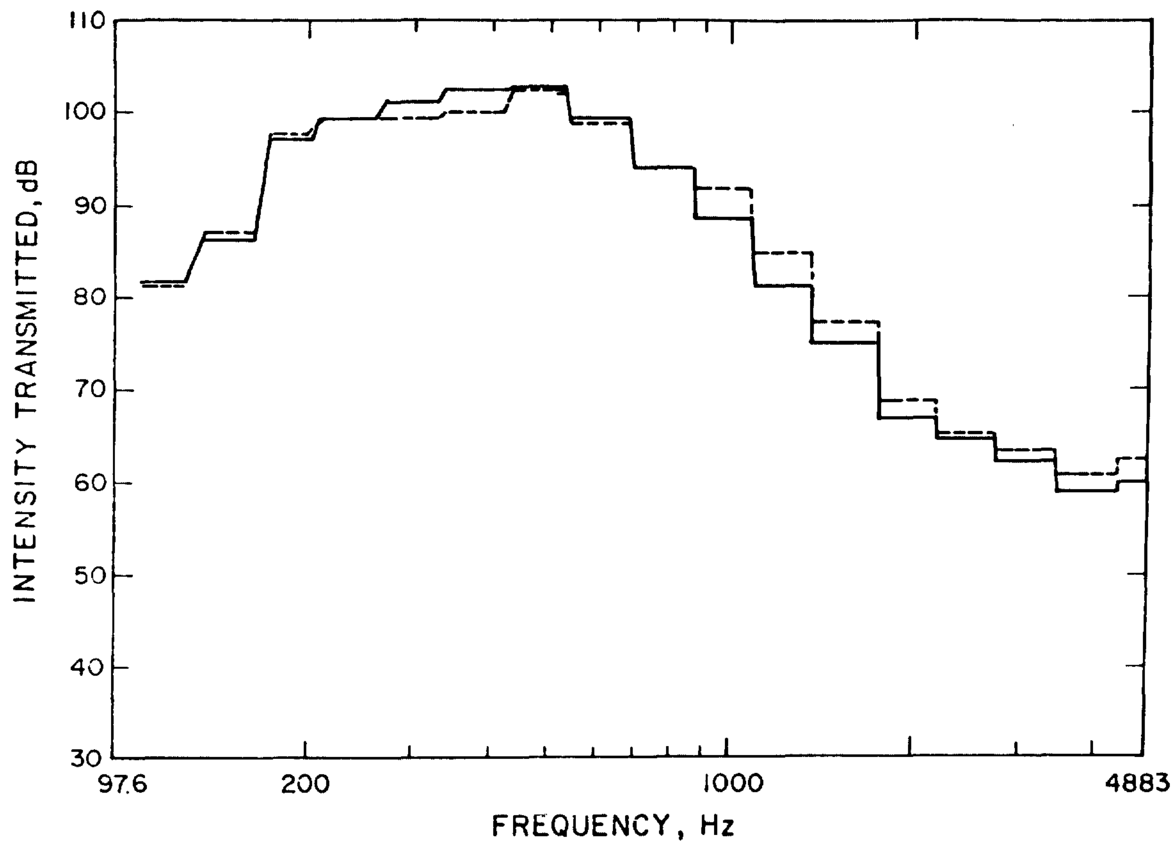


Figure 6. The effect of flanking noise on the door panel (Panel 4) transmitted intensity measured using the face-to-face microphone arrangement. —— blocked flanking pahts, ---- unblocked flanking paths.

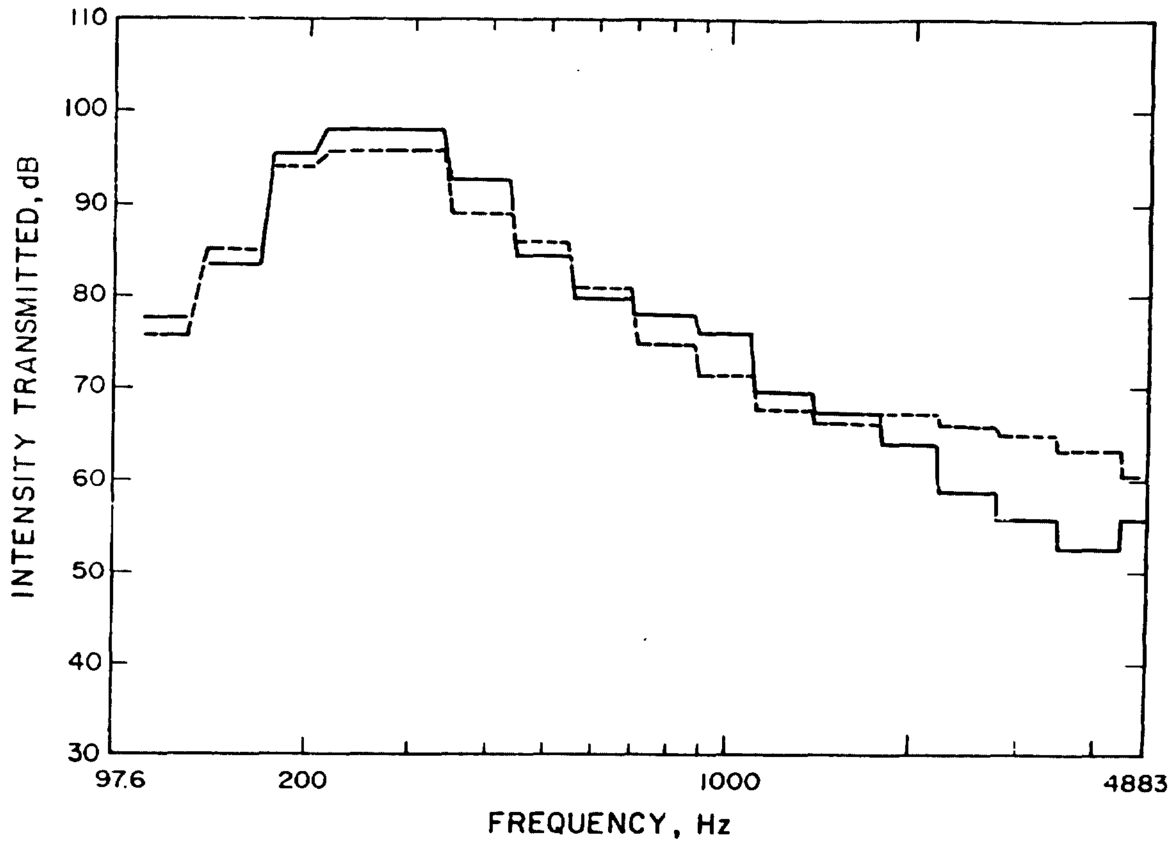


Figure 7. The effect of flanking noise on the door window (Panel 3) transmitted intensity measured using the side-by-side microphone arrangement. —— blocked flanking paths, ---- unblocked flanking paths.

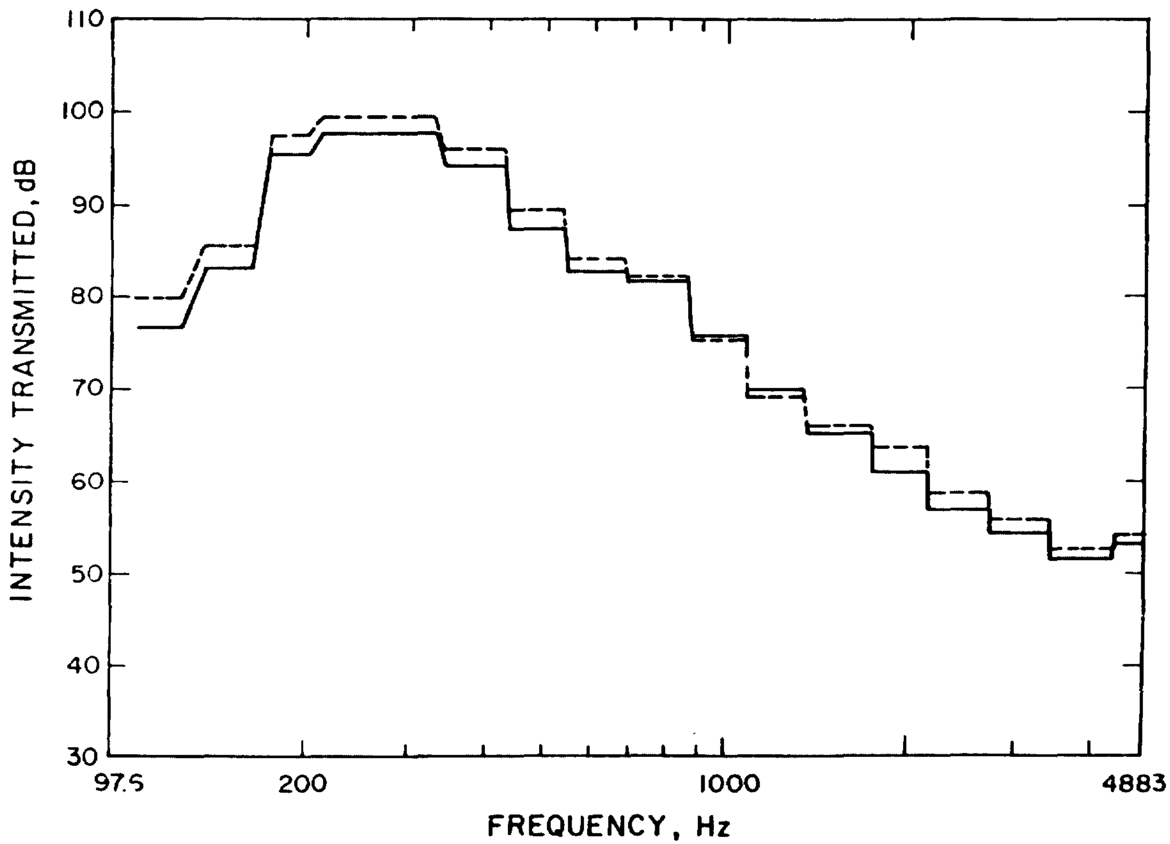


Figure 8. The effect of flanking noise on the door window (Panel 3) transmitted intensity measured using the face-to-face microphone arrangement. —— blocked flanking paths, ---- unblocked flanking paths.

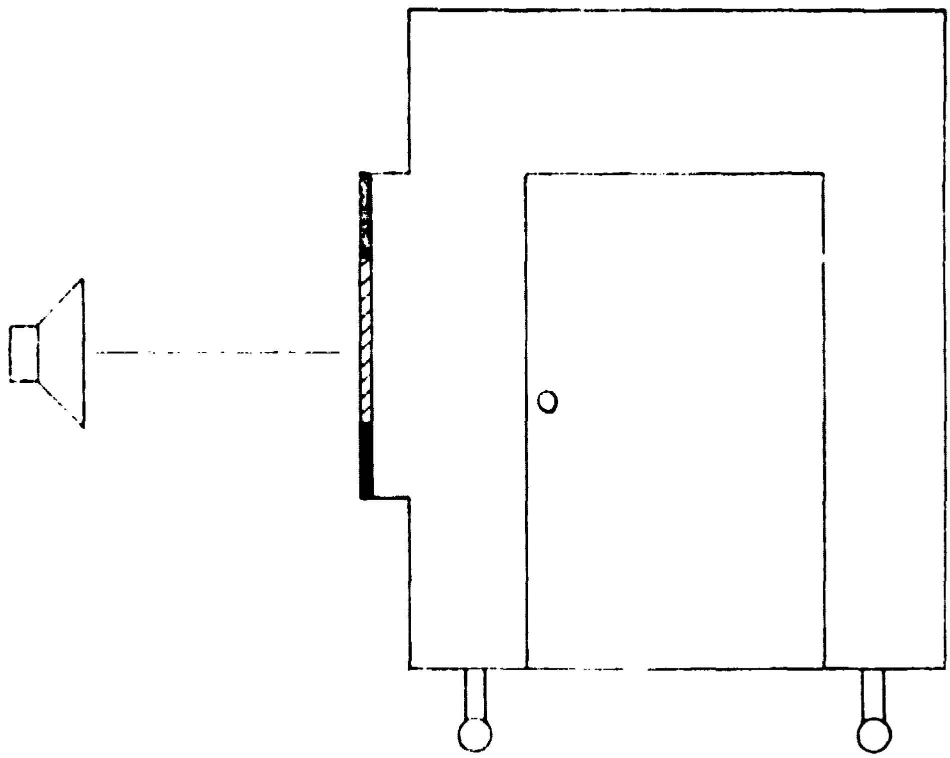


Figure 9. Set-up used to measure intensity in the presence of background noise.

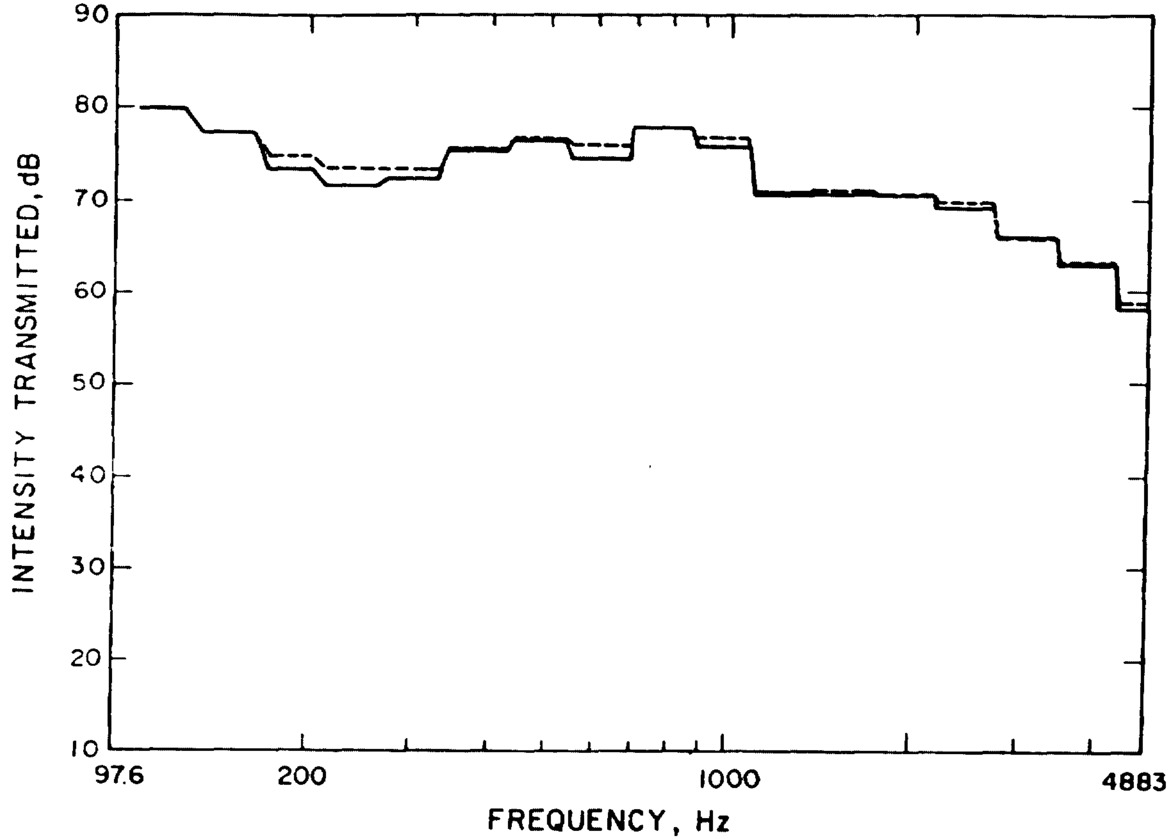


Figure 10. Acoustical intensity transmitted measured under the two different microphone arrangements: —— face-to-face, ---- side-by-side.

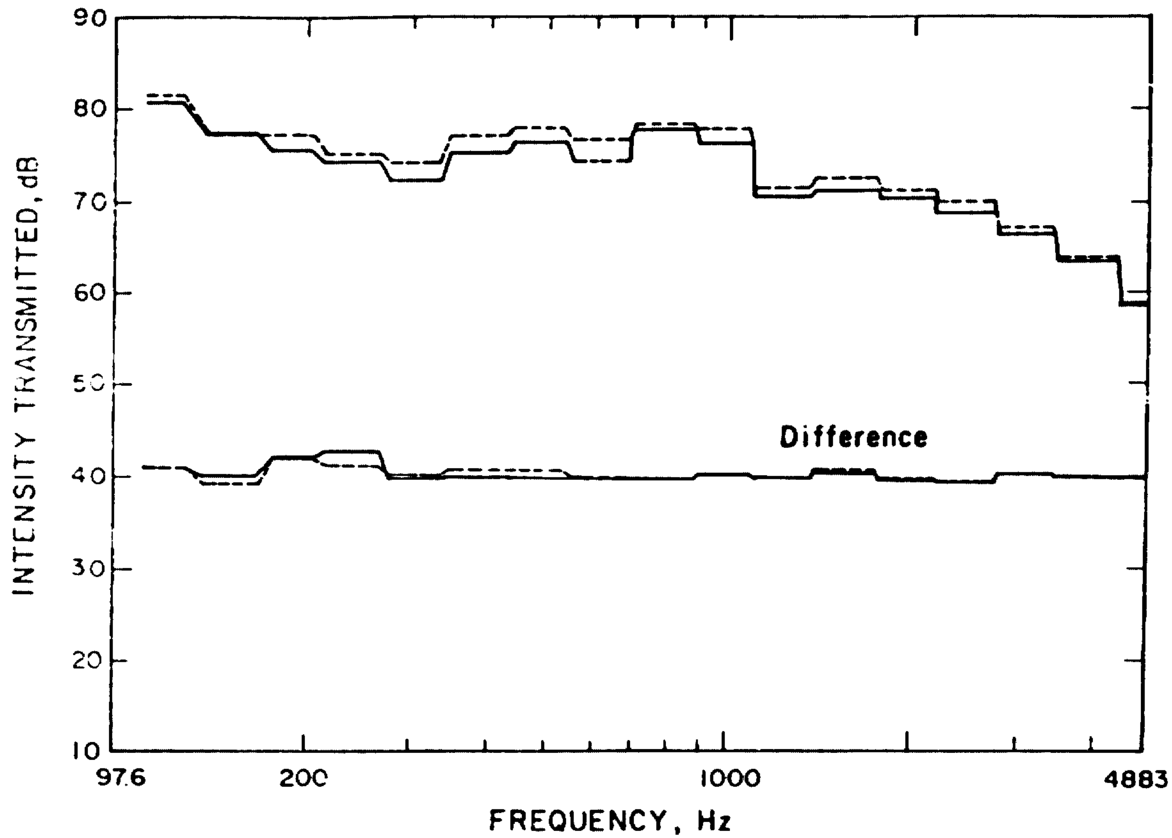


Figure 11. The difference between semi-anechoic and anechoic condition intensities measured using the two different microphone arrangements. ---- face-to-face, ---- side-by-side.

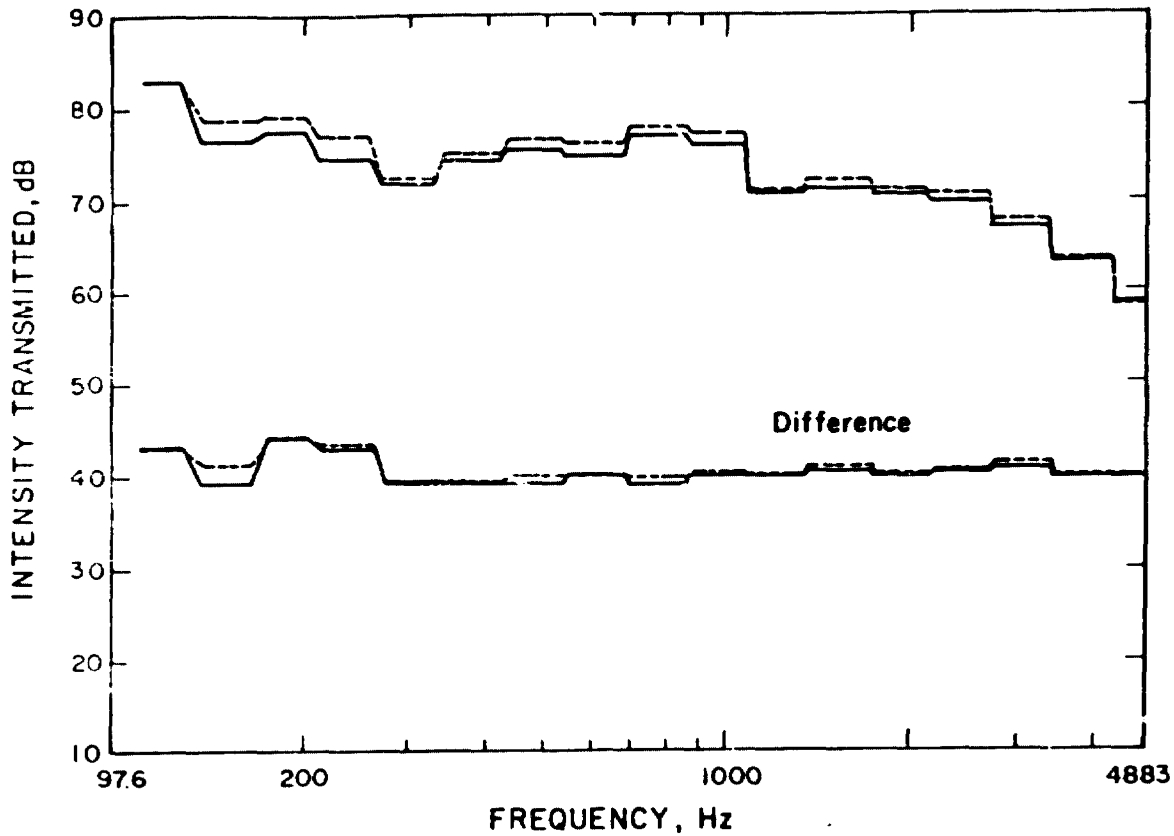


Figure 12. The difference between reverberant and anechoic condition intensities measured using the two different microphone arrangements. —— face-to-face, ---- side-by-side.

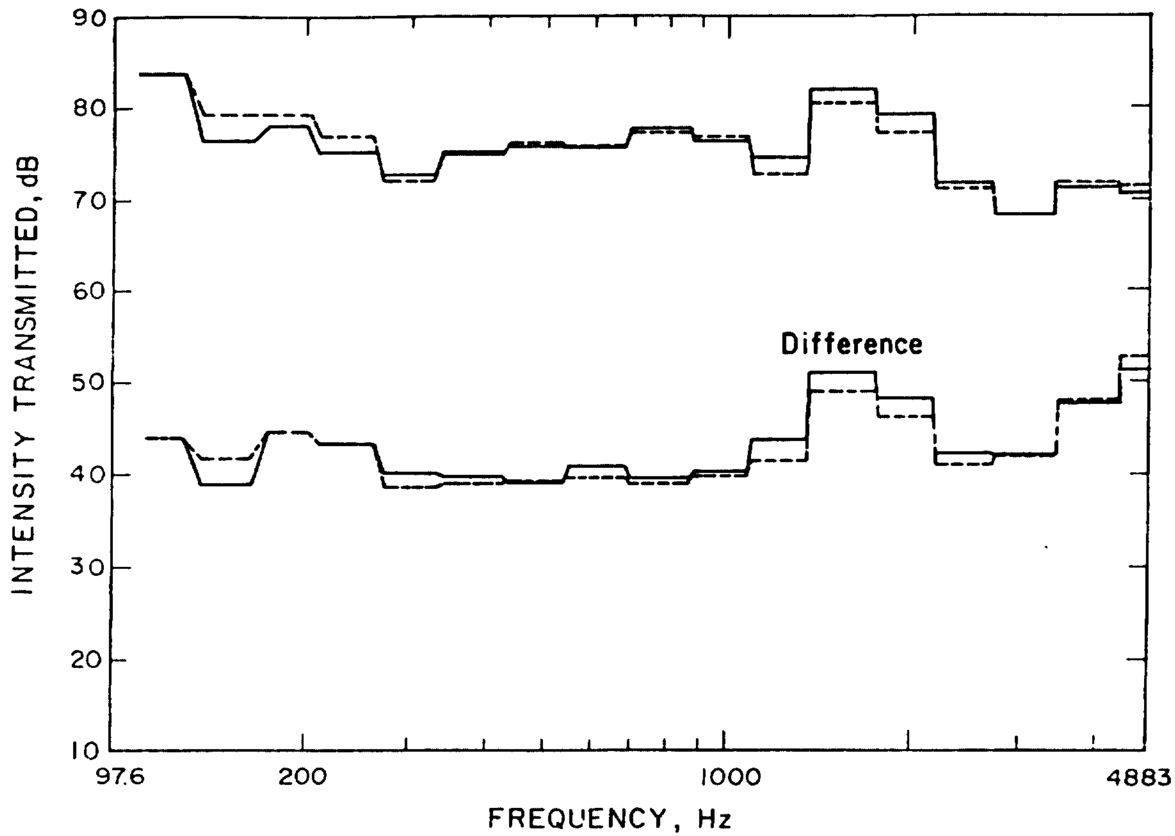


Figure 13. The difference between noisy and anechoic condition intensities measured using the two different microphone arrangements. ——— face-to-face, ---- side-by-side.